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THE FIRE ON THE CANADIAN COAST GUARD SHIP "LOUIS S. ST-LAURENT"

by

K.J. Mintz*

SUMMARY

The plastic laminated chipboard used in the cabin where the fire began has been shown to be capable of generating explosive gases when heated in an oxygen deficient atmosphere. When fresh air is introduced, an explosive mixture can be formed. This is the most probable origin of the reported "fireball" that caused the injuries and major part of the damage.

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INTRODUCTION

At approximately 11:48 a.m. March 6, 1982, fire was detected in the Captain's cabin of the Canadian Coast Guard icebreaker "Louis S. St-Laurent". When the crew opened the cabin door to fight the fire, a "fireball" emerged and travelled down the passageway at a rapid rate, severely burning three of the crew including the Captain. After the "fireball", the fire quickly spread to the adjacent cabins and then to the bridge, melting aluminum bulkheads and decks in its path and causing considerable damage before it could be brought under control.

As the "fireball" caused the only personal injuries and was an important turning point in the course of the fire, the Coast Guard asked CEAL to investigate its cause.

EXPERIMENTAL

The plastic laminated chipboard used for the walls and ceiling of the captain's cabin was the suspect material. The plastic is white for the ceiling board and imitation wood pattern for the wallboard on the exposed sides and black on the hidden sides. However, they are almost certainly made of the same chemical material.

The core is composed of small wood chips glued together in a random manner. A pyrogram gas chromatographic/mass spectrometric analysis showed the presence of phenols. Hence, the glue used is probably a phenolformaldehyde type.

BURNING IN AIR

Small pieces of the wood chips burnt with a very small flame when heated; the flame remained for a few seconds after heating was stopped. Under identical conditions, the plastic laminate did not produce a flame, but only glowed during the application of heat. In both cases, a small amount of grayish-white ash remained after combustion.

PARTIAL COMBUSTION CONDITIONS

To simulate the fire inside the closed cabin, a piece of ceiling tile was heated in an erlenmeyer flask closed off with a glass wool plug. After

ca. 10 min., the heating was stopped and the plug removed. A burning splint inserted into the mouth ignited a flame which propagated a few centimeters back into the flask and lasted a few seconds. This flame could be re-ignited several times over a couple of minutes. Similar results were obtained with a piece of the wallboard. During the heating of the samples, oils from the glue were distilled and trapped on the glass wool. They burnt easily even away from the explosive gases.

Additional burning tests were carried out on pieces of ceiling tile and wallboard for which the plastic laminate had been separated from the wood chip core. The erlenmeyer flasks were covered loosely with a beaker. The wood chip core produced first copious amounts of white smoke (water vapour), then some yellow smoke which condensed on the beaker and upper part of the flask in the form of oily droplets. The material remaining after combustion was a black char, probably mainly carbon. The plastic laminate required more heating to char and did not produce any yellow smoke or distillate.

Gas samples were taken by removing the beaker and opening the stop-cock of a previously evacuated glass bulb at the mouth of the erlenmeyer flask.

ANALYSIS OF THE GAS SAMPLES

The analysis was carried out by gas-liquid chromatography (Perkin-Elmer Sigma 1) in the Energy Research Laboratories. A 3-column, 2-detector system permits detection of all light gases up to C_5. Backflushing gives the total amount of higher molecular weight compounds. System A, which has been in routine use, used a He/H_2 mixture as the carrier gas. System B, which was just being set up at the time of these tests, uses Ar, so that hydrogen can be measured. The calibration for H_2 is only approximate.

Apart from air, the main components of the gas mixture were CO_2, CO, CH_4 and H_2. Only trace amounts of higher hydrocarbons were detected.

Table 1 summarizes the results obtained. The purpose of the chromatographic analyses was illustrative rather than quantitative. To make an accurate prediction of the quantities of gases that had been present in the cabin would have been a major project; little additional practical knowledge would have been obtained.

DISCUSSION

Without delving into the intricacies of the chemical reactions involved, we can obtain an approximate picture of how the explosive gas mixture is generated. Assume that the organic material has an approximate empirical formula of $C_xH_{2x}O_x$. For complete combustion with an ample supply of air, we have:

$$C_xH_{2x}O_x + x\ O_2 \rightarrow xCO_2 + xH_2O \qquad (1)$$

In the case of incomplete combustion,

$$C_xH_{2x}O_x + (O_2) \rightarrow CO,\ H_2O,\ CH_4,\ H_2,\ C \qquad (2)$$

As a further rough approximation, assume that all the free oxygen is consumed by (1). Then the final concentration of CO_2 should be about the same as the original concentration of O_2. The glc analysis indicates that the concentration of CO is about the same as the concentration of H_2 and about half that of CO_2. Using the above information, the final gas mixture is predicted to be: N_2 67%, CO_2 17%, CO 8%, CH_4 4%, H_2 4%.

The individual lower limits of flammability in air are (1): CO 12.5%, CH_4 5%, H_2 4%. Although, at first sight, this would indicate that the gas mixture is not explosive, Le Chatelier's Law must be used to calculate the combined lower explosive limit, L, (1):

$$L = \frac{100}{\frac{P_1}{L_1} + \frac{P_2}{L_2} + \frac{P_3}{L_3}} \qquad (3)$$

where L_1, L_2, L_3 are the individual explosive limits quoted above, and P_1, P_2, P_3 are the percentages of the gas, expressed in terms of the total combustibles.

The overall lower explosive limit for the mixture $CO:CH_4:H_2 = 2:1:1$, by Eq (3), is 8.6%, definitely lower than the 16% total combustibles predicted to be present. Hence, this mixture would be explosive if sufficient air were present.

An approximate flammability diagram, valid only for the above ratio of combustibles, was constructed (Fig. 1). The abscissa refers to the amount of N_2 + CO_2 added to air, i.e., 0% refers to normal air. (For the present purpose, primarily illustrative, it is sufficient to assume that CO_2 has the same effect as N_2.) The shaded area is the flammable region. If all the oxygen has been consumed during the smouldering combustion stage, the gas mixture can be represented by the circled point on the 0% air line. When air is added (e.g. opening the door), the concentration follows the dashed line until the rich limit (ca. one-third air by volume) is reached. If an ignition source of sufficient energy is present, then the mixture will explode.

Although the source of ignition is not known, it was probably not right at the entrance, but well inside the room. The explosion would push unburnt combustible gases down the passageway ahead of the flame front, thus accounting for the "fireball" reported. Its yellow colour is either due to the CH_4/air component or a mist of the decomposition products of the glue (the oily, yellow liquid observed in our laboratory experiments).

CONCLUSIONS

The chromatographic analyses demonstrate conclusively that explosive gases, specifically carbon monoxide, methane and hydrogen, are generated during a smouldering type of combustion of the ceiling tile and wallboard in a closed, but not necessarily sealed, environment. If fresh air is introduced along with an ignition source, an explosion can occur. This mechanism accounts for the events on the Louis S. St.-Laurent.

To prevent the occurrence of the fireball, either (1) the fire should have been contained without opening the door or (2) sources of ignition should not have been present, or (3) flammable materials, such as the ceiling tile and wallboard, should be removed. The last is the safest approach.

ACKNOWLEDGEMENTS

John Bossert of CEAL provided the description of the ship explosion given in the Introduction. Don Clugston and Pierre Lafontaine of the Energy Research Laboratories carried out the chromatographic analyses.

Table 1 - GLC analyses of combustion gases

Sample	Combustion time	System	CO/CO_2	CH_4/CO_2	H_2/CO_2
Ceiling Tile					
1 Wood chips	5 min	A	0.66	0.30	
2 Black plastic laminate and wood	5 min	A	0.42	0.10	
3 Black plastic laminate and wood	15 min	A	0.27	0.19	
		B		0.19	0.19
4 Black plastic laminate only	15 min	A	0.37	0.21	
5 Wood chips - very small quantity	5 min	A	0.16	0.12	
6 White plastic laminate only	15 min	A	0.16	0.09	
		B	0.18	0.11	0.11
7 Wood chips	5 min	A	0.58	0.18	
Wallboard					
1 Intact piece	10 min	A	0.31	0.02	
2 Decorative plastic laminate	10 min	A	0.20	0.04	

Fig. 1 - Flammability diagram